

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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| In re Patent Application of: |) |
| Satoko SHITAGAKI et al. |) |
| Application No.: 10/ 706,291 |) Examiner: YAMNITZKY |
| Filed: November 13, 2003 |) Group Art Unit: 1774 |
| For: QUINOXALINE DEVIVATIVES, |) |
| ORGANIC SEMICONDUCTOR DEVICE AND |) |
| ELECTROLUMINESCENT DEVICE |) |

VERIFICATION OF TRANSLATION

Commissioner for Patents
P.O.Box 1450
Alexandria, VA 22313-1450

Sir:

I, Sayaka Nakasako, C/O Semiconductor Energy Laboratory Co., Ltd. 398, Hase, Atsugi-shi, Kanagawa-ken 243-0036 Japan, a translator, herewith declare:

that I am well acquainted with both the Japanese and English Languages;

that I am the translator of the attached English translation of the Japanese Patent Application No. 2002-329251 filed on November 13, 2002; and

that to the best of my knowledge and belief the following is a true and correct English translation of the Japanese Patent Application No. 2002-329251 filed on November 13, 2002.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Date: this 7th day of September, 2007

Sayaka Nakasako
Name: Sayaka Nakasako

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[Reference Number] P006725
[Filing Date] November 13, 2002
[Attention] Commissioner, Patent Office

5 [Inventor]
[Address] 398 Hase, Atsugi-shi, Kanagawa-ken
c/o Semiconductor Energy Laboratory Co., Ltd.
[Name] Satoko SHITAGAKI
[Inventor]
10 [Address] 398 Hase, Atsugi-shi, Kanagawa-ken
c/o Semiconductor Energy Laboratory Co., Ltd.
[Name] Hiroko YAMAZAKI
[Inventor]
[Address] 398 Hase, Atsugi-shi, Kanagawa-ken
15 c/o Semiconductor Energy Laboratory Co., Ltd.
[Name] Satoshi SEO
[Applicant]
[Identification Number] 000153878
[Name] Semiconductor Energy Laboratory Co., Ltd.
20 [Representative] Shunpei YAMAZAKI
[Indication of Handlings]
[Number of Prepayment Note] 002543
[Payment Amount] 21,000
[List of Attachment]
25 [Attachment] Scope of Claims 1
[Attachment] Specification 1
[Attachment] Drawing 1
[Attachment] Abstract 1
[Proof] required

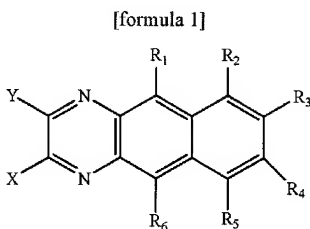
[Document Name] Specification

[Title of the Invention] QUINOXALINE DERIVATIVES, ORGANIC SEMICONDUCTOR DEVICE AND ELECTROLUMINESCENT DEVICE

[Scope of Claims]

5 [Claim 1]

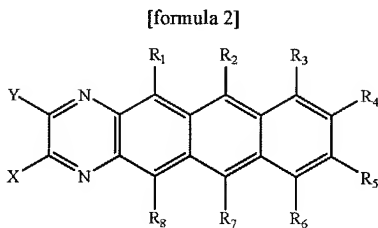
A quinoxaline derivative represented by general formula [formula 1].



10 (In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

15 [Claim 2]

A quinoxaline derivative represented by general formula [formula 2].



20 (In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R8 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or

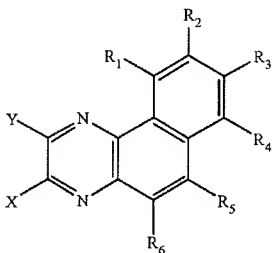
unsubstituted heterocyclic residue.)

[Claim 3]

A quinoxaline derivative represented by general formula [formula 3].

5

[formula 3]

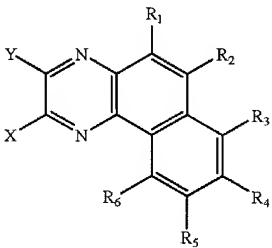


10 (In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

15 [Claim 4]

A quinoxaline derivative represented by general formula [formula 4].

[formula 4]

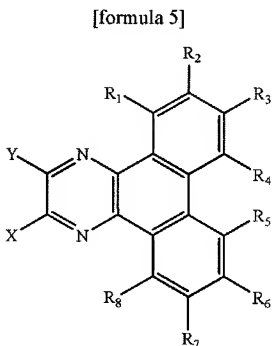


(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

5

[Claim 5]

A quinoxaline derivative represented by general formula [formula 5].



10

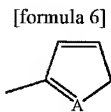
(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R8 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

15

[Claim 6]

The quinoxaline derivative according to any one of Claims 1 to 5, comprising the heterocyclic residue represented by general formula [formula 6].

20



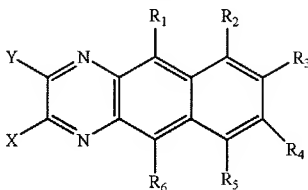
(In the formula, A represents S or O.)

[Claim 7]

An organic semiconductor device comprising a quinoxaline derivative represented by general formula [formula 7].

5

[formula 7]



(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

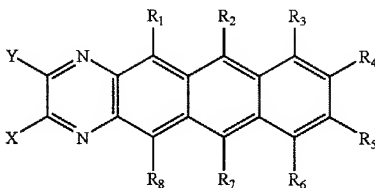
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[Claim 8]

An organic semiconductor device comprising a quinoxaline derivative represented by general formula [formula 8].

15

[formula 8]



(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R8 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

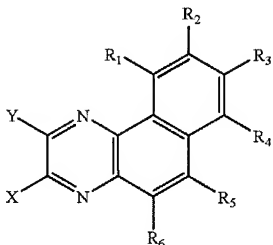
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[Claim 9]

An organic semiconductor device comprising a quinoxaline derivative represented by general formula [formula 9].

5

[formula 9]

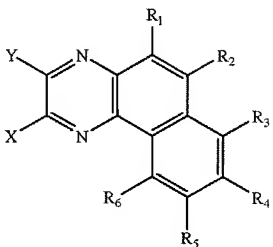


(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

[Claim 10]

An organic semiconductor device comprising a quinoxaline derivative represented by general formula [formula 10].

[formula 10]



(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

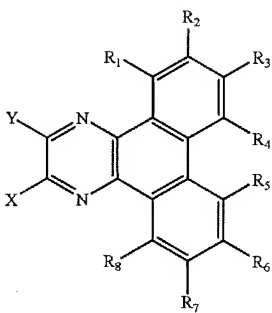
5

[Claim 11]

An organic semiconductor device comprising a quinoxaline derivative represented by general formula [formula 11].

10

[formula 11]



(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R8 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

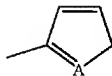
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[Claim 12]

The organic semiconductor device comprising the quinoxaline derivative according to any one of Claims 7 to 11, including a heterocyclic residue represented by general formula [formula 12].

20

[formula 12]

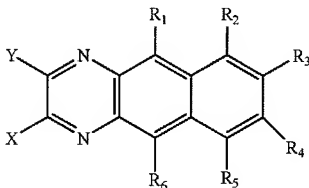


(In the formula, A represents S or O.)

[Claim 13]

- 5 An electroluminescent device characterized in that the quinoxaline derivative represented by general formula [formula 13] is used as an electron transporting material.

[formula 13]

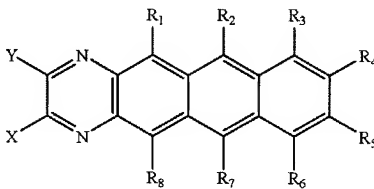


- 10 (In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R₁ to R₆ individually represent hydrogen, an alkyl group, an alkoxyl group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

15 [Claim 14]

An electroluminescent device characterized in that the quinoxaline derivative represented by general formula [formula 14] is used as an electron transporting material.

[formula 14]



20

(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R8 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

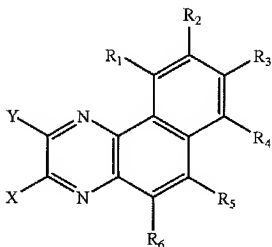
5

[Claim 15]

An electroluminescent device characterized in that the quinoxaline derivative represented by general formula [formula 15] is used as an electron transporting material.

10

[formula 15]



(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

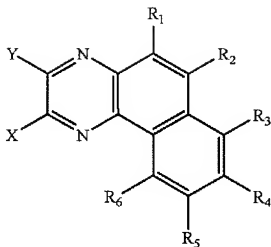
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[Claim 16]

An electroluminescent device characterized in that the quinoxaline derivative represented by general formula [formula 16] is used as an electron transporting material.

20

[formula 16]

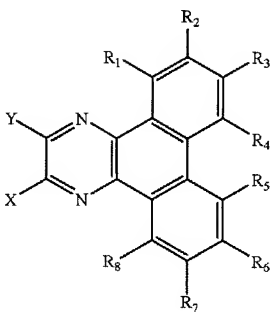


(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen,
 5 an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

[Claim 17]

An electroluminescent device characterized in that the quinoxaline derivative
 10 represented by general formula [formula 17] is used as an electron transporting material.

[formula 17]



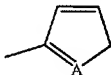
(In the formula, X and Y represent alkyl a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R8 individually represent hydrogen,
 15 an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or

unsubstituted heterocyclic residue.)

[Claim 18]

An electroluminescent device according to any one of Claims 13 to 17, characterized in that the quinoxaline derivative including the heterocyclic residue represented by general formula [formula 18] is used as an electron transporting material.

[formula 18]

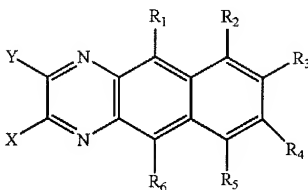


(In the formula, A represents S or O.)

[Claim 19]

An electroluminescent device characterized by comprising a light-emitting layer including a quinoxaline derivative represented by general formula [formula 19] and a guest material.

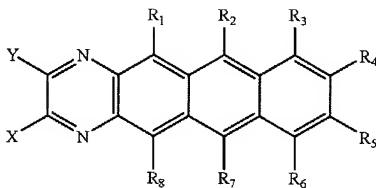
[formula 19]



(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

[Claim 20]

An electroluminescent device characterized by comprising a light-emitting layer including a quinoxaline derivative represented by general formula [formula 20] and a guest material.[formula 20]



5

(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R8 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

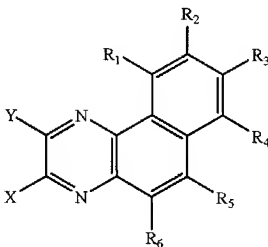
10

[Claim 21]

An electroluminescent device characterized by comprising a light-emitting layer including a quinoxaline derivative represented by general formula [formula 21] and a guest material.

15

[formula 21]



20

(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a

substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

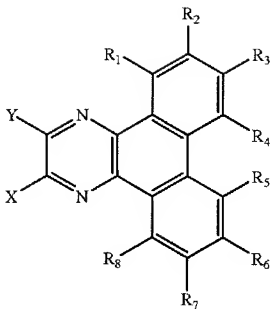
An electroluminescent device characterized by comprising a light-emitting layer including a quinoxaline derivative represented by general formula [formula 22] and a guest material.

[formula 22]

(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

[Claim 23]

An electroluminescent device characterized by comprising a light-emitting layer including a quinoxaline derivative represented by general formula [formula 23] and a guest material.

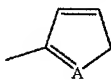


(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R8 individually represent hydrogen, an alkyl group, an alkoxyl group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

[Claim 24]

An electroluminescent device according to any one of Claims 19 to 23, characterized by comprising a light-emitting layer including a quinoxaline derivative comprising the heterocyclic residue represented by general formula [formula 24] and a guest material.

[formula 24]



(In the formula, A represents S or O.)

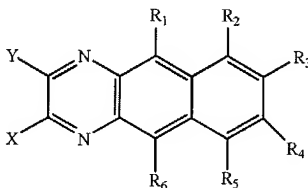
[Claim 25]

An electroluminescent device according to any one of Claims 19 to 24, characterized in that the guest material is a phosphorescent material.

[Claim 26]

An electroluminescent device characterized in that the quinoxaline derivative represented by general formula [formula 25] is used as a hole blocking material.

[formula 25]



5

(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxyl group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

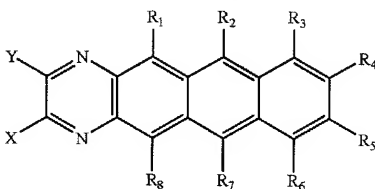
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[Claim 27]

An electroluminescent device characterized in that the quinoxaline derivative represented by general formula [formula 26] is used as a hole blocking material.

15

[formula 26]



20

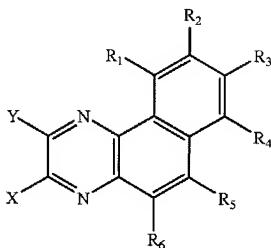
(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R8 individually represent hydrogen, an alkyl group, an alkoxyl group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

[Claim 28]

An electroluminescent device characterized in that the quinoxaline derivative represented by general formula [formula 27] is used as a hole blocking material.

5

[formula 27]

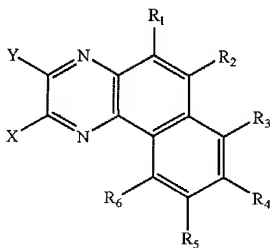


(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, 10 an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

[Claim 29]

15 An electroluminescent device characterized in that the quinoxaline derivative represented by general formula [formula 28] is used as a hole blocking material.

[formula 28]

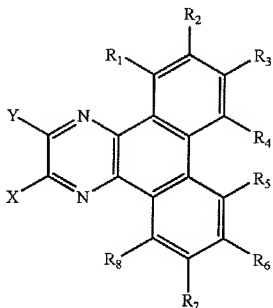


(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

[Claim 30]

An electroluminescent device characterized in that the quinoxaline derivative represented by general formula [formula 25] is used as a hole blocking material.

[formula 29]

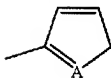


(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R8 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

[Claim 31]

An electroluminescent device according to any one of Claims 26 to 30, characterized in that the quinoxaline derivative comprising the heterocyclic residue represented by general formula [formula 30] is used as a hole blocking material.

[formula 30]



(In the formula, A represents S or O.)

5

[Claim 32]

An electroluminescent device according to any one of Claims 26 to 31, characterized by comprising:

- 10 a hole blocking layer comprising the hole blocking material; and
 the electroluminescent layer comprising the phosphorescent material.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

- 15 The present invention relates to quinoxaline derivatives used as an organic semiconductor material, an organic semiconductor device containing the quinoxaline derivative, and an electroluminescent device containing the quinoxaline derivative.

[0002]

[Prior Art]

- 20 Organic compounds have various material series compared with inorganic compounds, and so there is a possibility that various functional materials can be synthesized by an appropriate molecular design. In addition, a formation of organic compounds, for example, a film has excellent flexibility, and becomes adequately workable by polymerization. Therefore, photonics and electronics, each of which is formed with functional organic materials, have
25 attracted attention in recent years.

[0003]

For example, as an example of photoelectronic devices using organic semiconductor materials as functional organic materials, a solar battery or an electroluminescent device (also referred to as an organic electroluminescent device) is given. These devices utilize electrical

properties (carrier transportation properties) and photophysical properties (light absorption or light emission properties) of organic semiconductor materials. Above all, an electroluminescent device has achieved remarkable development.

[0004]

5 The basic structure of an electroluminescent device was explained by C. W. Tang et al. in 1987. The device, which is one type of a diode, has the structure composed of an organic thin film with an overall thickness of approximately 100 nm formed by stacking layers of organic compounds having hole transportation properties and organic compounds having electron transportation properties, interposed between a pair of electrodes. Light emission can
10 be observed from the compounds having electron transportation properties formed with light-emitting materials (phosphorescent materials) by applying voltage to the device. (For example, refer to Non-patent Literature 1.)

[0005]

[Non-patent Literature 1]

15 C. W. Tang and S. A. Vanslyke, "Organic electroluminescent diodes", Applied Physics Letters, Vol.51, No.12, 913-915 (1987)

[0006]

 Hereby, the combination of a hole transporting material and an electron transporting material is essential for the device containing organic semiconductor materials, especially,
20 elements which include heterojunctions, such as a solar battery or an electroluminescent device.

[0007]

 However, hole transporting materials account potentially for a large share of organic semiconductor materials in general. With respect to the absolute value of the carrier mobility, the hole mobility of hole transporting materials is several orders of magnitude larger than the
25 electron mobility of electron transporting materials. Therefore, electron transporting materials having excellent electron transportation properties have been hoped for.

[0008]

 Further, as electron transporting materials, it has been reported that quinoxaline derivatives, which are known as having electron transportation properties, are dimerized to improve the thermal
30 physical properties. (For example, refer to Patent Document 1.)

[0009]

[Patent Document 1]

Unexamined Patent Publication No. H6-207169

[0010]

5 However, electron transportation properties are deteriorated by the dimerization since interaction of molecules is weakened. In addition, physical property values such as the energy gaps of the dimerized quinoxaline derivatives are diverged largely from those of original quinoxaline derivatives.

[0011]

10 It has also been disclosed that thermal physical property values (glass transition point or melting point) are improved by introducing a condensed ring into a quinoxaline skeleton to form an adamant plane structure. (For example, refer to Patent Document 2.).

[0012]

[Patent Document 2]

15 Unexamined Patent Publication No. H9-13025

[0013]

 However, although this material has high thermal physical property values, the material has a demerit of being difficult in maintaining amorphous state and being susceptible to crystallization.

20 [0014]

 In addition, as electron transporting materials, materials having hole blocking properties (referred to as hole blocking materials especially in this case) are known. In this instance, wide ranging applications become possible since the hole blocking material has a function of blocking holes in addition to a function of transporting electrons. For example, it has been reported that, by
25 interposing a hole blocking material between a hole transporting layer and an electron transporting layer, holes are trapped in the hole transporting layer, and carriers in the hole transporting layer are selectively recombined, and then light is generated in an electroluminescent device. (For example, refer to Non-patent Literature 2.).

[0015]

30 [Non-patent Literature 2]

Yasunori KIJIMA, Nobutoshi ASAI and Shin-ichiro TAMURA, "A Blue Organic Light Emitting Diode", Japanese Journal of Applied Physics, vol. 38, 5274-5277 (1999)

[0016]

In addition, it has been reported that high efficient light emission can be obtained by using
5 hole blocking materials for forming a triplet light-emitting device. (For example, refer to Non-patent Literature 3.).

[0017]

[Non-patent Literature 3]

D. F. O'Brien, M. A. Baldo, M. E. Thompson and S. R. Forrest, "Improved energy transfer
10 in electrophosphorescent devices", Applied Physics Letters, vol. 74, No. 3, 442-444 (1999)

[0018]

Though a triplet light-emitting device is an effective art for a high efficient
electroluminescent device, the electroluminescent device cannot generate light efficiently without
using a hole blocking material. Consequently, the hole blocking material becomes an important
15 key.

[0019]

Hence, hole blocking materials have great importance among electron transporting
materials; however, the kinds of materials having both excellent electron transportation properties
and excellent hole blocking properties are highly limited in the present situation. As one of a few
20 examples, BCP (bathocuproin) can be used, which is used in Non-patent Literature 2 and
Non-patent Literature 3. However, the BCP deposited film is susceptible to crystallization, and has
significantly adverse effects on the reliability of devices in case of utilizing the BCP for actual
devices.

[0020]

Therefore, among electron transporting materials, a hole blocking material which has
25 excellent hole blocking properties and excellent film quality and is hardly crystallized has been
hoped for.

[0021]

[Problem to Be Solved by the Invention]

30 It is an object of the invention to provide quinoxaline derivatives which has excellent

electron transportation and hole blocking properties, and which can be formed into a film without being crystallized. It is another object of the invention to provide an organic semiconductor device and an electroluminescent device, which is one type of the organic semiconductor devices, each of which has high efficiency and high driving stability by forming
5 the organic semiconductor device and the electroluminescent device with the foregoing quinoxaline derivatives.

[0022]

[Means for solving the Problems]

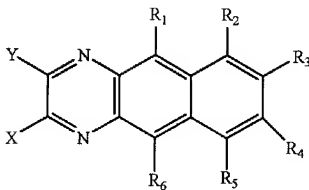
One aspect of the invention is to provide the following quinoxaline derivatives denoted by
10 reference numerals (1), (2), (3), (4), (5), and (6).

[0023]

(1) A quinoxaline derivative represented by general formula [formula 31].

[0024]

[formula 31]



15

[0025]

(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen,
20 an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

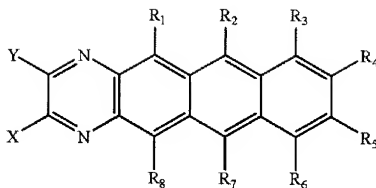
[0026]

(2) A quinoxaline derivative represented by general formula [formula 32].

[0027]

25

[formula 32]



[0028]

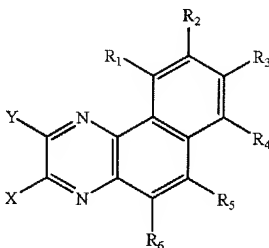
(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R8 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

[0029]

(3) A quinoxaline derivative represented by general formula [formula 33].

[0030]

[formula 33]



[0031]

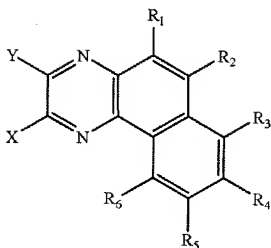
(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

[0032]

(4) A quinoxaline derivative represented by general formula [formula 34].

[0033]

[formula 34]



5 [0034]

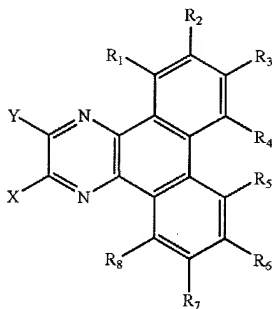
(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

10 [0035]

(5) A quinoxaline derivative represented by general formula [formula 35].

[0036]

[formula 35]



15

[0037]

(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a

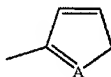
substituted or unsubstituted heterocyclic residue, and R1 to R8 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.)

[0038]

- 5 (6) The quinoxaline derivative according to any one of (1) to (5), comprising the heterocyclic residue represented by general formula [formula 36].

[0039]

[formula 36]



10

[0040]

(In the formula, A represents S or O.)

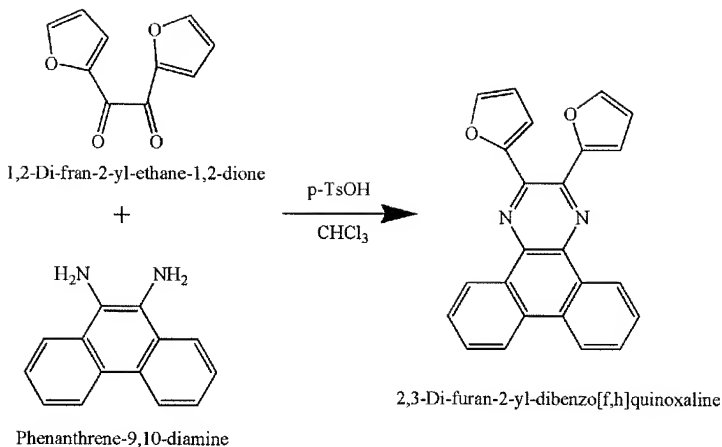
[0041]

- The quinoxaline derivatives according to the invention represented by the above (1) to
15 (6) can be synthesized by using diketone and diamine as materials. The synthesis method for the quinoxaline derivatives (FuQn) according to the invention is not limited to the following synthesis method. A synthesis scheme of the quinoxaline derivative represented by (1) is represented by way of example.

[0042]

20

[formula 37]



[0043]

Specifically, diketone and diamine are dissolved into solvent such as chloroform (dehydrated chloroform), alcohol (methanol, ethanol, propanol, butanol), or the like, and the mixture is stirred and refluxed. In the middle of the reflux, para-toluenesulfonic acid is added, and the mixture is further stirred and refluxed. The reaction time is preferably 1 ~ 24 hours.

[0044]

In addition, with respect to each the above structure of quinoxaline derivatives, X and Y are a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue. The quinoxaline derivatives have no plane structure, and so maintain an amorphous state in forming a film to prevent crystallization. Therefore, the above quinoxaline derivatives have excellent film formation properties compared with the quinoxaline derivatives in which X and Y have ring structures, which is disclose in Patent Document 2 explained in Prior Art.

[0045]

Further, electron transportation properties can be improved since electric charges are polarized in the case that X and Y have the above-described structure. In addition, a heterocyclic residue is preferably included in order to improve electron transportation properties.

[0046]

In another aspect, the invention relates to an organic semiconductor device including an electroluminescent device using quinoxaline derivatives in the above structures ((1) to (6)).

[0047]

5 In another aspect, the invention relates to an electroluminescent device using the quinoxaline derivatives as electron transporting materials by taking advantages that the quinoxaline derivatives in the above structures ((1) to (6)) have excellent electron transportation properties.

[0048]

10 In another aspect, the invention relates to an electroluminescent device characterized by having a light-emitting layer which contains a quinoxaline derivative in the above structures ((1) to (6)) and a guest material. The quinoxaline derivatives according to the invention can form a light-emitting layer by being used as a host material with another guest material since the quinoxaline derivatives have wide energy gaps.

[0049]

15 In addition, the quinoxaline derivatives according to the invention are especially preferable in the case of using a phosphorescent material as a guest material, which requires a host material to have a wide energy gap.

[0050]

20 The quinoxaline derivatives according to the invention can also be used as guest materials for blue light emission since the quinoxaline derivatives according to the invention have wide energy gaps and have a fluorescent wavelength around 450 nm. The quinoxaline derivatives according to the invention are materials that have electron transportation properties and are effective for reducing a driver voltage since it is generally known that membrane resistance can be reduced by using a material having electron transportation properties as a guest material.

25 [0051]

In another aspect, the invention relates to an electroluminescent device characterized by using quinoxaline derivatives in the above structures ((1) to (6)) as hole blocking materials since the quinoxaline derivatives have excellent hole blocking properties.

30 [0052]

In the above structure, since the quinoxaline derivatives according to the invention have wide energy gaps, the electroluminescent device preferably has a light-emitting layer containing phosphorescent materials, which are required wide energy gaps in the case of using the quinoxaline derivatives for a hole blocking layer as hole blocking materials.

5

[0053]

[Embodiment Mode of the Invention]

The structure of an electroluminescent device according to the invention has basically an electroluminescent layer (a hole injecting layer, a hole transporting layer, a light-emitting layer, a blocking layer, an electron transporting layer, and an electron injecting layer) containing the above-mentioned quinoxaline derivatives in the above structures ((1) to (6)), interposed between a pair of electrodes (an anode and a cathode). For instance, in the electroluminescent device having the following structure: anode/ hole injecting layer/ light-emitting layer/ electron transporting layer/ cathode; anode/ hole injecting layer/ hole transporting layer/ light-emitting layer/ electron transporting layer/ cathode; anode/ hole injecting layer/ hole transporting layer/ light-emitting layer/ electron transporting layer/ electron injecting layer/ cathode; anode/ hole injecting layer/ hole transporting layer/ light-emitting layer/ hole blocking layer/ electron transporting layer/ cathode; anode/ hole injecting layer/ hole transporting layer/ light-emitting layer/ hole blocking layer/ electron transporting layer/ electron injecting layer/ cathode; or the like, the quinoxaline derivatives can be used for the electron transporting layer, the blocking layer, or the light-emitting layer.

20

[0054]

In addition, the electroluminescent device according to the invention is preferably supported by a substrate. The substrate is not especially limited, and any substrate used for conventional electroluminescent devices can be used, for example, a glass substrate, a quartz substrate, a transparent plastic substrate.

25

[0055]

As an anode material for the electroluminescent device according to the invention, a metal (at least 4.0 eV), an alloy, an electric conductive compound, and a mixture of the above materials having a high work function are preferably used. As a specific example of anode

30

materials, in addition to ITO (indium tin oxide), or IZO (indium zinc oxide) which is a mixture of indium oxide and zinc oxide (ZnO) of from 2 ~ 20%, aurum (Au), platinum (Pt), nickel (Ni), tungsten (W), chromium (Cr), molybdenum (Mo), iron (Fe), cobalt (Co), copper (Cu), palladium (Pd), metal nitride (TiN), or the like can be used.

5 [0056]

On the other hand, as a cathode material, a metal (at most 3.8 eV), an alloy, an electric conductive compound, and a mixture of the above having a low work function are preferably used. As a specific example of cathode materials, transition metals including rare earth metals can be used, in addition to elements belonging to the first group or the second group of the periodic table of the elements, that is, alkali metals such as Li or Cs, alkali earth metals such as Mg, Ca, and Sr, alloys including the above elements (Mg:Ag, Al:Li), or compounds (LiF, CsF, CaF₂). In addition, the cathode can also be formed to have a lamination structure including metals (including alloys) such as Al, Ag, or ITO and the foregoing materials.

[0057]

15 An anode or a cathode is formed by depositing the above described anode materials and cathode materials respectively by vapor deposition, sputtering, or the like, to form a thin film. The anode and cathode are preferably formed to have thicknesses of 10 ~ 500 nm.

[0058]

20 Within the electroluminescent device according to the invention, light which results from the recombination of carriers in the electroluminescent layer is emitted to outside through either the anode or the cathode, or both of the electrodes. Therefore the anode is formed with a transparent material in the case of emitting light through the anode, and the cathode is formed by a transparent material in the case of emitting light through the cathode.

[0059]

25 In addition, a known material can be used for the electroluminescent layer, and either a low molecular weight material or a high molecular weight material can be used. As materials for forming the light-emitting layer, not only materials composed of only organic compound materials but also that partly including inorganic compound materials can be used.

[0060]

30 The electroluminescent layer is formed by stacking, in combination, a hole injecting

layer formed with a hole injecting material, a hole transporting layer formed with a hole transporting material, a light-emitting layer formed with a light-emitting material, a blocking layer formed with a blocking material, an electron transporting layer formed with an electron transporting material, an electron injecting layer formed with an electron injecting material, and the like.

[0061]

In the case of using quinoxaline derivatives for the electron transporting layer in the invention, the electroluminescent layer is formed by stacking at least the light-emitting layer by the anode side and the electron transporting layer containing the quinoxaline derivative by the cathode side. The other layers such as the hole injecting layer and the hole transporting layer can be stacked in combination as appropriate. Specific materials for forming the hole injecting layer and the hole transporting layer are explained hereinafter.

[0062]

As hole injecting materials, porphyrin compounds are useful among organic compounds, and phthalocyanine (hereinafter, H₂-Pc), copper phthalocyanine (hereinafter, Cu-Pc), or the like can be used. Further, chemically-doped conductive polymer compounds can be used, such as polyethylene dioxythiophene (hereinafter, PEDOT) doped with polystyrene sulfonate (hereinafter, PSS), polyaniline, or polyvinyl carbazole (PVK).

[0063]

As hole transporting materials, aromatic amine (that is, the one having a benzene ring-nitrogen bond) compounds are preferably used. For example, in addition to the above-mentioned TPD, derivatives thereof such as 4,4'-bis[N-(1-naphthyl)-N-phenyl-amino]-biphenyl (hereinafter, α -NPD) is widely used. Also widely used are star burst aromatic amine compounds, including: 4,4',4''-tris(N,N-diphenyl-amino)-triphenyl amine (hereinafter, TDATA); and 4,4',4''-tris[N-(3-methylphenyl)-N-phenyl-amino]-triphenyl amine (hereinafter, MTDATA).

[0064]

As light emitting materials, in specific, metal complexes such as tris(8-quinolinolato) aluminum (hereinafter, Alq₃), tris(4-methyl-8-quinolinolato) aluminum (hereinafter, Almq₃), bis(10-hydroxybenzo[h]-quinolinato) beryllium (hereinafter, BeBq₂),

bis(2-methyl-8-quinolinolato)-(4-hydroxy-biphenyl)-aluminum (hereinafter, BA1q), bis [2-(2-hydroxyphenyl)-benzooxazolato] zinc (hereinafter, Zn(BOX)₂), and bis [2-(2-hydroxyphenyl)-benzothiazolato] zinc (hereinafter, Zn(BTZ)₂) are useful. Also, fluorescent dyes are useful.

5 [0065]

For forming the electron transporting layer containing quinoxaline derivatives, any one of the above-mentioned quinoxaline derivatives ((1) to (6)) are used.

[0066]

In the invention, in the case of using quinoxaline derivatives as a host material for the
10 light-emitting layer, the light-emitting layer is formed of at least quinoxaline derivatives as a host material and a light-emitting layer including a guest material. The other layers such as the hole injecting layer, the hole transporting layer, the electron transporting layer, and the blocking layer can be stacked in combination as appropriate. In this instance, the hole injecting layer and the hole transporting layer can be formed with the same materials as those used for forming the
15 electron transporting layer with the use of quinoxaline derivatives.

[0067]

As electron transporting materials, above-mentioned metal complexes having a quinoline skeleton or benzoquinoline skeleton, such as the aforementioned Alq₃, Almq₃, BeBq₂; and mixed ligand complexes such as Balq are useful. In addition, metal complexes having
20 oxazole-based and thiazole-based ligands such as Zn(BOX)₂ and Zn(BTZ)₂ can be used. Further, oxadiazole derivatives such as 2-(4-biphenyl)-5-(4-tert-butylphenyl)-1,3,4-oxadiazole (hereinafter, PBD), and 1,3-bis[5-(p-tert-butylphenyl)-1,3,4-oxadiazole-2-yl] benzene (hereinafter, OXD-7); triazole derivatives such as
3-(4-tert-butylphenyl)-4-phenyl-5-(4-biphenyl)-1,2,4-triazole (hereinafter, TAZ) and
25 3-(4-tert-butylphenyl)-4-(4-ethylphenyl)-5-(4-biphenyl)-1,2,4-triazole (hereinafter, p-EtTAZ); and phenanthroline derivatives such as bathophenanthroline (hereinafter, BPhen) and bathocuproin (hereinafter, BCP) can be used in addition to metal complexes.

[0068]

As a blocking material, the above-mentioned BA1q, OXD-7, TAZ, p-EtTAZ, BPhen,
30 BCP, or the like can be used.

[0069]

The light-emitting layer in this instance is formed by combining the quinoxaline derivatives ((1) to (6)) as a host material and a guest material.

[0070]

5 As a guest material for forming the light-emitting layer, a triplet light-emitting material (phosphorescent material) such as tris(2-phenylpyridine)iridium (hereinafter, Ir(ppy)₃); and 2,3,7,8,12,13,17,18-octaethyl-21H, 23H-porphyrin-platinum (hereinafter, PtOEP) can be used in addition to quinacridone, diethylquinacridone (DEQ), rubrene, perylene, DPT, Co-6, PMDFB, BTX, ABTX, DCM, DCJT.

10 [0071]

On the other hand, quinoxaline derivatives can be used as a guest material for the electroluminescent layer in the invention. In this instance, the electroluminescent layer is formed of at least quinoxaline derivatives as a guest material and an electroluminescent layer including a host material. The other layers such as the hole injecting layer, the hole
15 transporting layer, the electron transporting layer, and the blocking layer can be stacked in combination as appropriate. The materials thereof can be the same as those described above.

[0072]

Further, in the case of using quinoxaline derivatives for the blocking layer in the invention, the electroluminescent layer is formed by stacking at least the light-emitting layer by
20 the anode side and the blocking layer containing quinoxaline derivatives by the cathode side. The other layers such as the hole injecting layer, the hole transporting layer, and the electron transporting layer can be stacked in combination as appropriate. In this instance, the hole injecting layer and the hole transporting layer can be formed with the same materials as those used for forming the electron transporting layer with the use of quinoxaline derivatives. In
25 addition, the electron transporting layer can be formed with the same materials as those used for forming the light-emitting layer with the use of quinoxaline derivatives as a host material.

[0073]

In the case of using quinoxaline derivatives for the blocking layer, a triplet light-emitting material is preferably used in addition to the materials which are described above
30 as light-emitting materials. Complexes having platinum or iridium as a central metal can be

used. As the triplet light-emitting material, tris(2-phenylpyridine)iridium (hereinafter, Ir(ppy)₃); and 2,3,7,8,12,13,17,18-octaethyl-21H, 23H-porphyrin-platinum (hereinafter, PtOEP) can be given.

[0074]

5 [Examples]

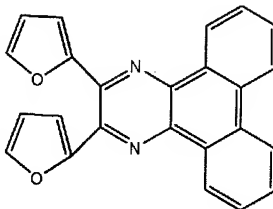
Hereinafter, the invention will be explained with synthesis examples, examples, and comparative examples according to the invention, but not limited to these examples.

[0075]

(Synthesis Example 1)

10 [0076]

[formula 38]



[0077]

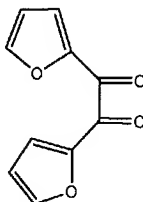
15 (Synthesis of 2,3-Di-furan-2-yl-dibenzo[f,h]quinoxaline)

In 1.90 g (10 mmol) of furyl as diketone represented by general formula [formula 39] and 2.14 g (10mmol) of 9,10-diaminonaphthalene as diamine, each of which was in a recovery flask, dehydrated chloroform (300 ml) was added. This obtained mixture was stirred and refluxed. After 30 minutes from starting to heat, a spatula of para-toluenesulfonic acid was added and the mixture was stirred and refluxed for 24 hours. After the reaction was completed, the reaction mixture was extracted with HCl_{aq}, NaHCO₃_{aq}, and H₂O. MgSO₄ (anhydrous) was added to the obtained solution and the mixture was stirred all night. The solution was evaporated with an evaporator and then was dried under reduced-pressure at room temperature. The product was purified by column chromatography (developing solvent: toluene, R_f=0.80). After the column purification, yellow green powder was purified by sublimation and then pale

yellow needle crystals are obtained. As a result of differential scanning calorimetric (DSC) analysis of the pale yellow needle crystals, the melting point was 202 °C. Further, as a result of infrared absorption spectrum measurement shown in FIG. 9, it is probable that the reaction was advanced from the fact that each peak of vicinity of the absorption of from 3500 ~ 3300 cm⁻¹ derived from -NH₂ of an original material and vicinity of the absorption of 1680 cm⁻¹ derived from α-diketone has disappeared.

[0078]

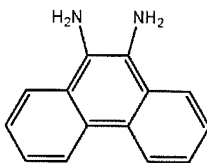
[formula 39]



10

[0079]

[formula 40]



15 [0080]

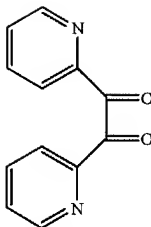
(Synthesis Example 2)

The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 41] and diamine shown in general formula [formula 42] were used. The obtained quinoxaline derivative is represented by general formula [formula 43].

20

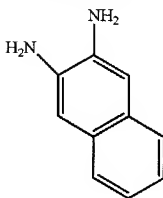
[0081]

[formula 41]



[0082]

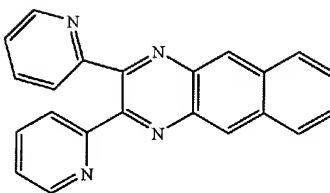
[formula 42]



5

[0083]

[formula 43]



10

[0084]

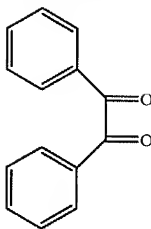
(Synthesis Example 3)

The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 44] and diamine shown in general formula [formula 45] were used. The obtained quinoxaline derivative is represented by general formula [formula 46].

15

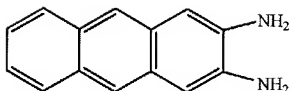
[0085]

[formula 44]



5 [0086]

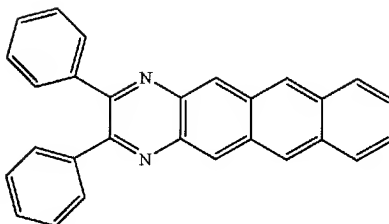
[formula 45]



[0087]

10

[formula 46]



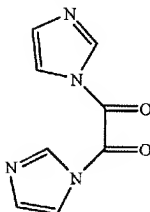
[0088]

(Synthesis Example 4)

15 The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 47] and diamine shown in general formula [formula 48] were used. The obtained quinoxaline derivative is represented by general formula [formula 49].

[0089]

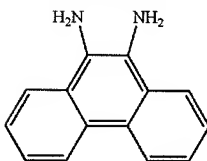
[formula 47]



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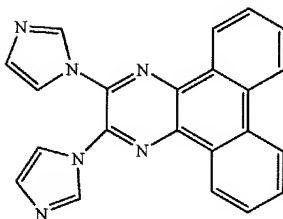
[0090]

[formula 48]



10 [0091]

[formula 49]



[0092]

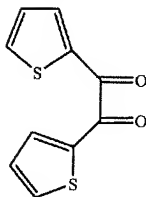
15 (Synthesis Example 5)

The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 50] and diamine

shown in [formula 51] were used. The obtained quinoxaline derivative is represented by general formula [formula 52].

[0093]

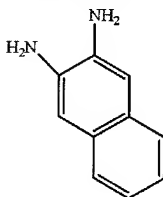
[formula 50]



5

[0094]

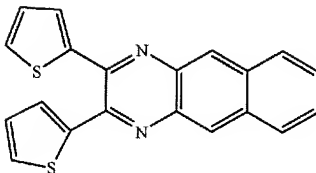
[formula 51]



10

[0095]

[formula 52]



15 [0096]

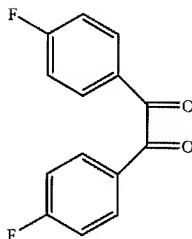
(Synthesis Example 6)

The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general [formula 53] and diamine shown

in general formula [formula 54] were used. The obtained quinoxaline derivative is represented by general formula [formula 55].

[0097]

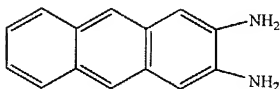
[formula 53]



5

[0098]

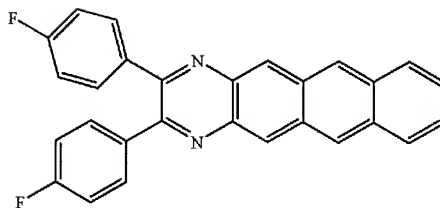
[formula 54]



10

[0099]

[formula 55]



15 [0100]

(Synthesis Example 7)

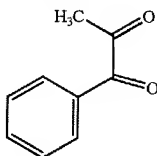
The reaction was carried out in accordance with the same procedures as those conducted

in Synthesis Example 1 except that diketone shown in general formula [formula 56] and diamine shown in general formula [formula 57] were used. The obtained quinoxaline derivative is represented by general formula [formula 58].

[0101]

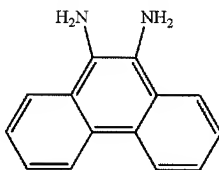
5

[formula 56]



[0102]

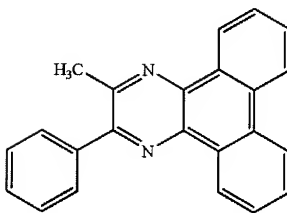
[formula 57]



10

[0103]

[formula 58]



15

[0104]

(Synthesis Example 8)

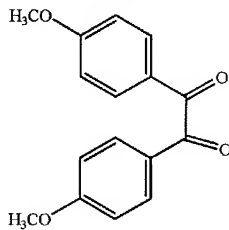
The reaction was carried out in accordance with the same procedures as those conducted

in Synthesis Example 1 except that diketone shown in general formula [formula 59] and diamine shown in general formula [formula 60] were used. The obtained quinoxaline derivative is represented by general formula [formula 61].

[0105]

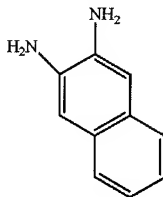
5

[formula 59]



[0106]

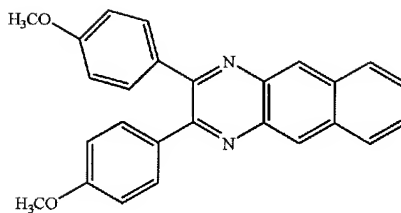
[formula 60]



10

[0107]

[formula 61]



15

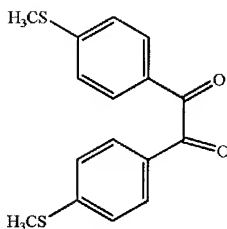
[0108]

(Synthesis Example 9)

The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 62] and diamine shown in general formula [formula 63] were used. The obtained quinoxaline derivative is represented by general formula [formula 64].

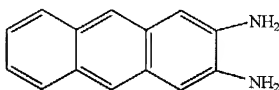
[0109]

[formula 62]



10 [0110]

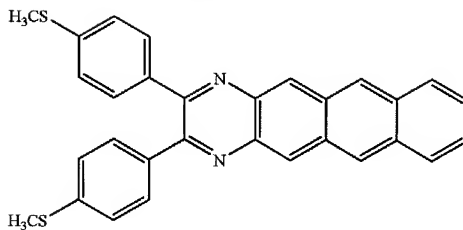
[formula 63]



[0111]

15

[formula 64]



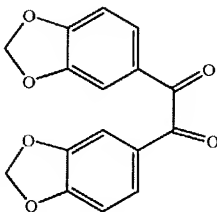
[0112]

(Synthesis Example 10)

The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 65] and diamine shown in general formula [formula 66] were used. The obtained quinoxaline derivative is represented by general formula [formula 67].

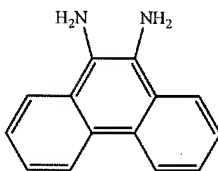
[0113]

[formula 65]



10 [0114]

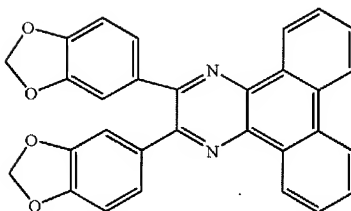
[formula 66]



[0115]

15

[formula 67]



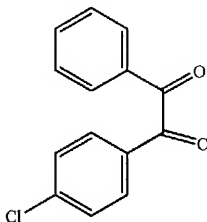
[0116]

(Synthesis Example 11)

The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 68] and diamine shown in general formula [formula 69] were used. The obtained quinoxaline derivative is represented by general formula [formula 70].

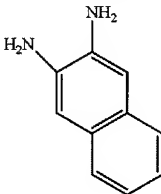
[0117]

[formula 68]

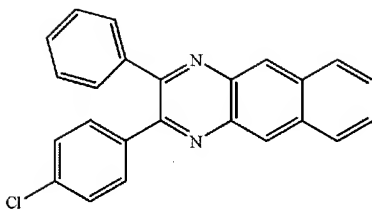


[0118]

[formula 69]



[formula 70]



[0120]

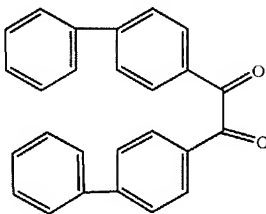
(Synthesis Example 12)

5 The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 71] and diamine shown in general formula [formula 72] were used. The obtained quinoxaline derivative is represented by general formula [formula 73].

[0121]

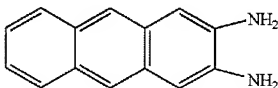
10

[formula 71]



[0122]

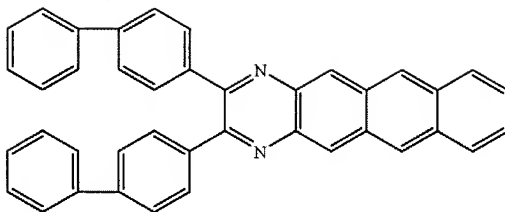
[formula 12]



15

[0123]

[formula 32]



[0124]

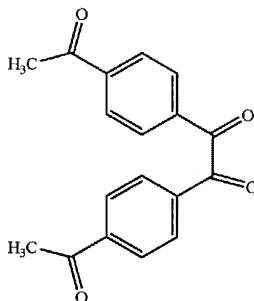
(Synthesis Example 13)

5 The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 74] and diamine shown in general formula [formula 75] were used. The obtained quinoxaline derivative is represented by general formula [formula 76].

[0125]

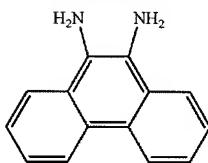
10

[formula 74]



[0126]

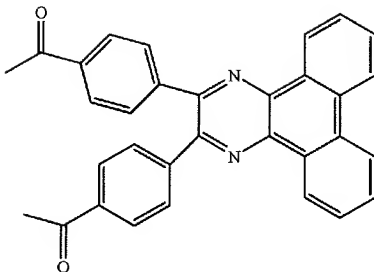
[formula 75]



15

[0127]

[formula 76]



5

[0128]

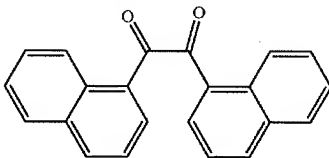
(Synthesis Example 14)

The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 77] and diamine shown in general formula [formula 78] were used. The obtained quinoxaline derivative is represented by general formula [formula 79].

10

[0129]

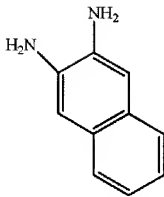
[formula 77]



15

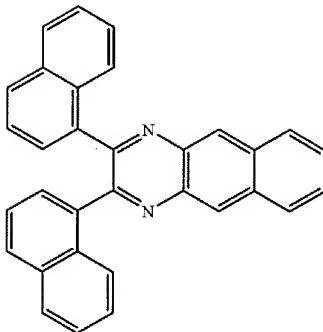
[0130]

[formula 78]



[0131]

[formula 79]



5

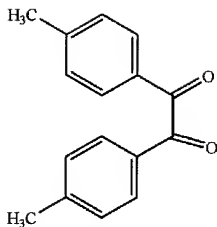
[0132]

(Synthesis Example 15)

The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 80] and diamine shown in general formula [formula 81] were used. The obtained quinoxaline derivative is represented by general formula [formula 82].

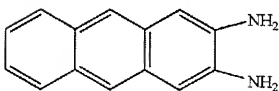
[0133]

[formula 80]



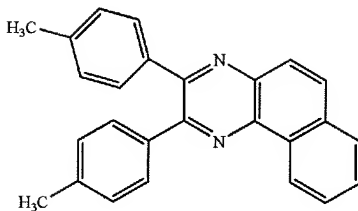
[0134]

[formula 81]



[0135]

[formula 82]



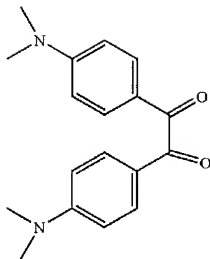
[0136]

(Synthesis Example 16)

The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 83] and diamine shown in general formula [formula 84] were used. The obtained quinoxaline derivative is represented by general formula [formula 85].

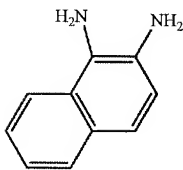
[0137]

[formula 83]



[0138]

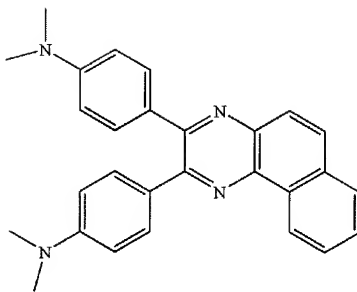
[formula 84]



5

[0139]

[formula 85]



10

[0140]

(Synthesis Example 17)

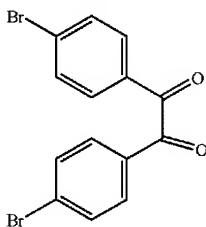
The reaction was carried out in accordance with the same procedures as those conducted

in Synthesis Example 1 except that diketone shown in general formula [formula 86] and diamine shown in general formula [formula 87] were used. The obtained quinoxaline derivative is represented by general formula [formula 88].

[0141]

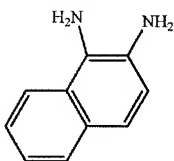
5

[formula 86]



[0142]

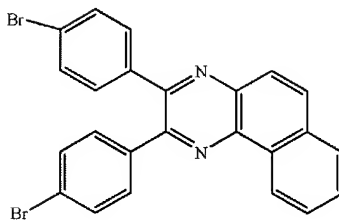
[formula 87]



10

[0143]

[formula 88]



15

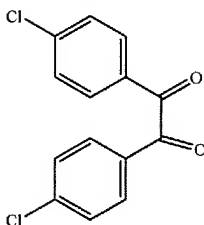
[0144]

(Synthesis Example 18)

The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 89] and diamine shown in general formula [formula 90] were used. The obtained quinoxaline derivative is represented by general formula [formula 91].

5 [0145]

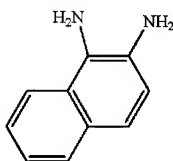
[formula 89]



[0146]

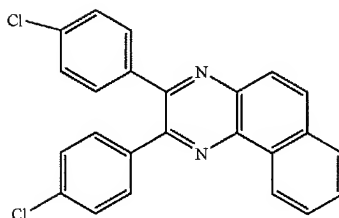
10

[formula 90]



[0147]

[formula 91]



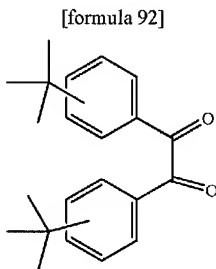
15

[0148]

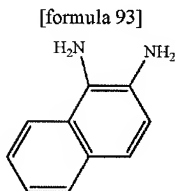
(Synthesis Example 19)

The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 92] and diamine shown in general formula [formula 93] were used. The obtained quinoxaline derivative is represented by general formula [formula 94].

[0149]



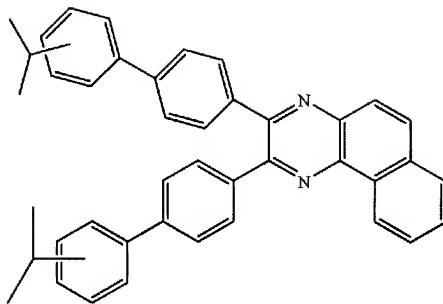
10 [0150]



[0151]

15

[formula 94]



[0152]

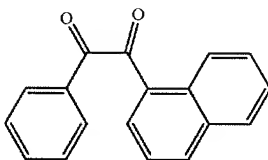
(Synthesis Example 20)

5 The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 95] and diamine shown in general formula [formula 96] were used. The obtained quinoxaline derivative is represented by general formula [formula 97].

[0153]

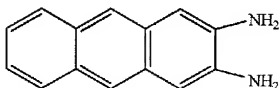
10

[formula 95]



[0154]

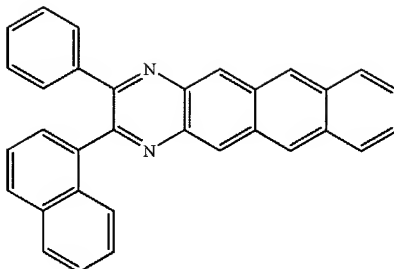
[formula 96]



15

[0155]

[formula 49]



[0156]

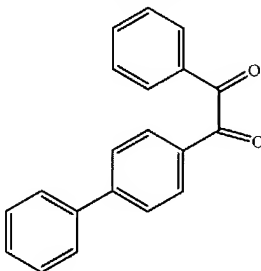
(Synthesis Example 21)

5 The reaction was carried out in accordance with the same procedures as those conducted in Synthesis Example 1 except that diketone shown in general formula [formula 98] and diamine shown in general formula [formula 99] were used. The obtained quinoxaline derivative is represented by general formula [formula 100].

[0157]

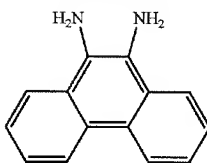
10

[formula 98]



[0158]

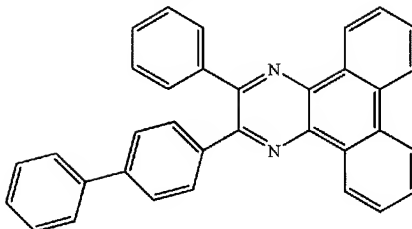
[formula 99]



15

[0159]

[formula 100]



5

[0160]

(Example 1)

In this example, an electroluminescent device manufactured in such a way that a part of an electroluminescent layer is formed using quinoxaline derivatives according to the invention will be explained. A device configuration of an electroluminescent device formed over a substrate will be explained with reference to FIG. 1 in this example.

10

[0161]

First, a first electrode 101 of an electroluminescent device is formed over a substrate 100. In this example, the first electrode 101 serves as an anode. The first electrode 101 is formed of ITO (indium tin oxide), which is a transparent conductive film, to have a thickness of 110 nm by sputtering. As the sputtering employed here, bipolar sputtering, ion beam sputtering, facing targets sputtering, or the like can be used.

15

[0162]

Next, an electroluminescent layer 102 is formed over the first electrode (anode) 101. This example will explain the case that the electroluminescent layer 102 is formed to have a lamination structure composed of a hole injecting layer 111, a hole transporting layer 112, a light-emitting layer 113, and an electron transporting layer 114; and that quinoxaline derivatives according to the invention are used for the electron transporting layer 114.

20

[0163]

The hole injecting layer 111 is formed as the following procedure: a substrate provided

25

with the first electrode 101 is fixed to a substrate holder of a commercial vacuum vapor deposition system in such a way that the surface on which the first electrode 101 is formed is down; copper phthalocyanine (hereinafter, Cu-Pc) is set in an evaporation source installed inside the vacuum vapor deposition system; and then, the hole injecting layer 111 is formed to have a thickness of 20 nm by vapor deposition by a resistance heating method.

[0164]

Next, the hole transporting layer 112 is formed with a material having excellent hole transportation properties. Here, 4,4'-bis[N-(1-naphthyl)-N-phenyl-amino]-biphenyl (hereinafter, α -NPD) is deposited to have a thickness of 30 nm by the same method.

[0165]

Next, the light-emitting layer 113 is formed. Holes and electrons are recombined within the light-emitting layer 113 to generate luminescence. Here, Alq₃ is deposited to have a thickness of 50 nm by the same method.

[0166]

And the electron transporting layer 114 is formed. The electron transporting layer 114 is formed with quinoxaline derivatives according to the invention. As the quinoxaline derivatives, materials represented by synthesis examples 1-21 can be used; in this example, 2,3-Di-furan-2-yl-dibenzo[f,h]quinoxaline represented by Synthesis Example 1 is deposited to have a thickness of 20 nm by the same method.

[0167]

As described above, after the electroluminescent layer 102 having a lamination structure is formed, a second electrode 103 which serves as a cathode is formed by sputtering or vapor deposition. In this example, the second electrode 103 can be formed over the electroluminescent layer 102 by depositing aluminum-lithium alloys (Al:Li) to have a thickness of 100 nm by sputtering.

[0168]

Accordingly, an electroluminescent device can be formed using quinoxaline derivatives according to the invention. This example explained the case where the first electrode is formed over the substrate with an anode material to serve as an anode; however, the invention is not limited thereto. The first electrode can be formed with a cathode material to serve as a cathode.

In this case (in the case of interchanging the anode and the cathode), the lamination sequence which was shown in this example is reversed. In addition, in this example, the first electrode (anode) is transparent and light generated in the electroluminescent layer is emitted through the first electrode (anode); however, the invention is not limited thereto. Light can be emitted through the second electrode (cathode) by selecting a material suitable for keeping the transmittance.

[0169]

As described in this example, an electron transporting layer which has excellent electron transportation and blocking properties can be formed by using quinoxaline derivatives according to the invention for forming the electron transporting layer, so that an electroluminescent device which has excellent luminous efficiency and which starts operating at low voltage can be obtained.

[0170]

(Example 2)

In this example, an electroluminescent device which is formed in such a way that a part of an electroluminescent layer is formed using quinoxaline derivatives according to the invention in accordance with the procedures different from that described in the example 1 will be explained. Specifically, the case that quinoxaline derivatives according to the invention are used to form a light-emitting layer of the electroluminescent layer will be explained.

[0171]

In a similar procedure as that conducted in the example 1, a first electrode 201 is formed, and an electroluminescent layer 202 is formed over the first electrode 201 by vapor deposition.

[0172]

A hole injecting layer 211 is formed in contact with the first electrode 201. As a material for forming the hole injecting layer 211, a known hole injecting material can be used. In this example, the hole injecting layer 211 is formed of Cu-Pc to have a thickness of 20 nm by vapor deposition.

[0173]

Next, a hole transporting layer 212 is formed. As a material for forming the hole transporting layer 212, a known hole transporting material can be used. In this example, the

hole transporting layer 212 is formed of α -NPD to have a thickness of 30 nm by vapor deposition.

[0174]

Next, a light-emitting layer 213 is formed. In this example, quinoxaline derivatives according to the invention (including materials represented by Synthesis Examples 1-21) can be used as a host material for forming the light-emitting layer 213, and a known light-emitting material can be used as a guest material for forming the light-emitting layer 213. Accordingly, in this example, 2,3-Di-furan-2-yl-dibenzo[f,h]quinoxaline represented by Synthesis Example 1 among quinoxaline derivatives and perylene are deposited by co-evaporation to have a thickness of 30 nm.

[0175]

Next, an electron transporting layer 214 is formed. As a material for forming the electron transporting layer 214, a known electron transporting material can be used. Specifically, BAQ, PBD, OXD-7, BCP, or the like can be used. In this example, the electron transporting layer 214 is formed to have a thickness of 20 nm using quinoxaline derivatives used for forming the light-emitting layer, in particular, 2,3-Di-furan-2-yl-dibenzo[f,h]quinoxaline by vapor deposition.

[0176]

And after forming the electroluminescent layer 202 to have a lamination structure, a second electrode 203 is formed in accordance with the same procedure as that conducted in Example 1. Consequently, an electroluminescent device can be obtained.

[0177]

As described in this example, it is extremely effective to use quinoxaline derivatives according to the invention as the host material for forming the light-emitting layer for increasing luminous efficiency, because the wide energy gap of quinoxaline derivatives can be utilized effectively.

[0178]

(Example 3)

In this example, the case in which a light-emitting layer is formed using quinoxaline derivatives according to the invention and a configuration is different from that explained in

Example 2 will be explained. In this configuration, structures except those of a light-emitting layer and an electron transporting layer are the same as those described in the example 2 and will not be further explained.

[0179]

5 In this example, quinoxaline derivatives according to the invention are used as a guest material for forming a light-emitting layer 313, which is one component of the electroluminescent layer 302 interposed between a first electrode 301 and a second electrode 303 as shown in FIG. 3. As the quinoxaline derivatives used here, materials represented by Synthesis Examples 1-21 can be used.

10 [0180]

The light-emitting layer 313 can be formed by co-evaporation of the quinoxaline derivatives and CBP serving as a host material. As the host material, a known material can be used. Specifically, TPD, α -NPD, TCTA, PBD, OXD-7, BCP, or the like can be used.

[0181]

15 The quinoxaline derivatives according to the invention can be used as a guest material for blue light emission since it has a wide energy gap and shows phosphorescent wavelength around 450 nm. In addition, it is known that the quinoxaline derivatives according to the invention are materials having electron transportation properties. It is also generally known that membrane resistance is reduced by using materials having carrier transportation properties
20 as a guest material. (Refer to “45th NIKKEI MICRODEVICES Seminar, Leading Edge of Organic EL” Nikkei Business Publications., Inc., NIKKEI MICRODEVICES, pp.3.1-3.12). Therefore, a driving voltage can be reduced by using quinoxaline derivatives according to the invention as a guest material for forming a light-emitting layer as described in this example.

[0182]

25 (Example 4)

In this example, an electroluminescent device that is formed in such a way that a part of an electroluminescent layer is formed using quinoxaline derivatives according to the invention having a different structure from that described in the example 1 will be explained. Specifically, the case that quinoxaline derivatives according to the invention are used for forming a hole
30 blocking layer of the electroluminescent layer will be explained.

[0183]

A first electrode 401 is formed in accordance with the same procedures conducted in Example 1. An electroluminescent layer 402 is formed over the first electrode 401 by vapor deposition.

5 [0184]

First, a hole injecting layer 411 is formed on the first electrode 401. As a material for forming the hole injecting layer 411, a known hole injecting material can be used. In this example, the hole injecting layer 411 is formed to have a thickness of 20 nm with Cu-Pc by vapor deposition.

10 [0185]

Next, a light-emitting layer 412 is formed. As a material for forming the light-emitting layer 412, a known light-emitting material can be used. In this example, the light-emitting layer 412 is formed to have a thickness of 30 nm with α -NPD by vapor deposition.

[0186]

15 Next, a hole blocking layer 413 is formed. The hole blocking layer 413 is formed with the quinoxaline derivatives according to the invention. As the quinoxaline derivatives, materials represented by Synthesis Examples 1-21 can be used. In this example, 2,3-Di-furan-2-yl-dibenzo[f,h]quinoxaline represented by Synthesis Example 1 is deposited by the same method to have a thickness of 20 nm.

20 [0187]

Next, an electron transporting layer 415 is formed. As a material for forming the electron transporting layer 415, a known electron transporting material can be used. In this example, the electron transporting layer 415 is formed to have a thickness of 30 nm with Alq₃ by vapor deposition.

25 [0188]

And after forming the electroluminescent layer 402 to have a lamination structure, a second electrode 403 is formed in accordance with the same procedure as that conducted in Example 1. Consequently, an electroluminescent device can be obtained.

[0189]

30 As described in this example, luminous efficiency can be improved by forming the hole

blocking layer 413 using the quinoxaline derivatives according to the invention because holes can be trapped in the light-emitting layer 412.

[0190]

(Example 5)

5 Device characteristics of an electroluminescent device having the configuration described in Example 1 (ITO/ Cu-Pc (20 nm)/ α -NPD (30 nm)/ Alq₃ (30 nm)/ FuQn (20 nm)/ CaF (1 nm)/ Al) were measured. As quinoxaline derivatives (FuQn) in this example, 2,3-Di-furan-2-yl-dibenzo[f,h]quinoxaline represented by Synthesis Example 1 was used. Plot 3 in FIGS. 5 to 8 is shown for the measurement results. With regard to the luminance-current
10 characteristics shown in FIG. 5, plot 3 shows that a luminance of approximately 4000 cd/m² was achieved at a current density of 100 mA/cm².

[0191]

With regard to the luminance-voltage characteristics shown in FIG. 6, plot 3 shows that a luminance of approximately 1000 cd/m² was achieved at an applied voltage of 8 V.

15 [0192]

With regard to the current efficiency-luminance characteristics shown in FIG. 7, plot 3 shows that a current efficiency of approximately 2.8 cd/A was obtained at a luminance of 100 cd/m².

[0193]

20 Further, with regard to the current-voltage characteristics shown in FIG. 8, plot 3 shows that a current of approximately 0.4 mA flowed at an applied voltage of 7 V.

[0194]

(Comparative Example 1)

Device characteristics of an electroluminescent device having the configuration(ITO/
25 Cu-Pc (20 nm)/ α -NPD (30 nm)/ Alq₃ (30 nm)/ CaF (1 nm)/ Al in which an electron transporting layer formed of quinoxaline derivatives is not included, which is different from the device configuration measured in Example 5, were measured. Plot 1 in FIGS. 5 to 8 shows the measurement results. With regard to the luminance-current characteristics shown in FIG. 5, plot 1 shows that a luminance of approximately 4000 cd/m² was achieved at a current density of 100
30 mA/cm². The result is similar to that of the device measured in Example 5.

[0195]

With regard to the luminance-voltage characteristics shown in FIG. 6, plot 1 shows that a luminance of approximately 6000 cd/m^2 was achieved at an applied voltage of 8 V. In this instance, the luminance with the applied current has increased largely because the overall thickness of the electroluminescent layer is thin since an electron transporting layer is not included. Therefore, it should not be understood that the electroluminescent device in this instance has better characteristics than those of the electroluminescent device described in Example 2.

[0196]

In addition, with regard to the current efficiency-luminance characteristics shown in FIG. 7, plot 1 shows that a current efficiency of approximately 2.2 cd/A was obtained at a luminance of 100 cd/m^2 . Therefore, the current efficiency of the device structure is worse than that of the device structure in Example 2. This result shows that the device structure in Example 2 has high luminance efficiency since quinoxaline derivatives for forming the electron transporting layer has high hole blocking properties to trap holes in the light-emitting layer.

[0197]

With regard to the current-voltage characteristics shown in FIG. 8, plot 1 shows that a current of approximately 1 mA flowed at an applied voltage of 7 V. As in the case with FIG. 6, it should not be understood that the electroluminescent device having this structure has better characteristics than those of the electroluminescent device in Example 2 since the amount of current flow depends on the thickness of an electroluminescent layer.

[0198]

(Comparative Example 2)

Device characteristics of an electroluminescent device in Example 5 having the configuration (ITO/ Cu-Pc (20 nm)/ α -NPD (30 nm)/ Alq₃ (30 nm)/ BCP (20 nm)/ CaF (1 nm)/ Al in which an electron transporting layer is formed using bathocuproin (hereinafter, BCP), which has been conventionally used as a blocking material, instead of quinoxaline derivatives according to the invention were measured. Plot 2 in FIGS. 5 to 8 shows the measurement results. With regard to the luminance-current characteristics shown in FIG. 5, plot 2 shows that a luminance of approximately 4000 cd/m^2 was achieved at a current density of 100 mA/cm^2 .

The result is similar to that of the device measured in Example 5.

[0199]

With regard to the luminance-voltage characteristics shown in FIG. 6, plot 2 shows that a luminance of only about 200 cd/m^2 was obtained at an applied voltage of 8 V. Therefore, the characteristics of the device using bathocuproin are inferior in electron injection transportation properties to the electroluminescent device having an electron transporting layer formed using the quinoxaline derivatives according to the invention.

[0200]

With regard to the current efficiency-luminance characteristics shown in FIG. 7, plot 2 shows that a current efficiency of approximately 3.1 cd/A was obtained at a luminance of 100 cd/m^2 . As a whole, the characteristics of the electroluminescent device in this instance are similar to those of the electroluminescent device including the electron transporting layer formed using the quinoxaline derivatives according to the invention. Therefore, as regards the current efficiency-luminance characteristics, it was shown that the quinoxaline derivatives according to the invention can maintain almost the same level of blocking properties as those of the conventional BCP.

[0201]

Further, with regard to the current-voltage characteristics shown in FIG. 8, plot 2 shows that a current of approximately 0.08 mA flowed at an applied voltage of 7 V. From the fact that electroluminescent device containing quinoxaline derivatives is superior in current-voltage characteristics to the electroluminescent device containing BCP when they has the same thickness, it is probable that electron injection transportation properties of the electroluminescent device are improved by using quinoxaline derivatives.

[0202]

(Example 6)

The state of the film surface of a thin film formed of the quinoxaline derivatives according to the invention will be explained in this example. FIG. 10A shows a sample in which a thin film is formed of quinoxaline derivatives to have a thickness of about 50 nm over a substrate and which is sealed with a sealing substrate. The thin film of quinoxaline derivatives in this case was a stable film without crystallization of the surface thereof.

[0203]

(Comparative Example 3)

5 A sample was manufactured in accordance with the same procedure conducted in Example 6 except that a thin film of BCP was formed instead of forming a thin film of quinoxaline derivatives. As a result, the thin film of BCP was crystallized over time as shown in FIG. 10B.

[Effect of the Invention]

10 According to the invention, quinoxaline derivatives which have excellent electron transporting properties and hole blocking properties, and which can be formed into a film without being crystallized were obtained. Accordingly, organic semiconductor devices and electroluminescent devices which have high efficiency and high driving stability can be provided by manufacturing the organic semiconductor devices and the electroluminescent devices which are one type of the organic semiconductor devices with the above quinoxaline derivatives.

15

[Brief Description of Drawings]

[FIG. 1] An explanatory view of a configuration of an electroluminescent device according to the invention.

20 [FIG. 2] An explanatory view of a configuration of an electroluminescent device according to the invention.

[FIG. 3] An explanatory view of a configuration of an electroluminescent device according to the invention.

[FIG. 4] An explanatory view of a configuration of an electroluminescent device according to the invention.

25 [FIG. 5] A graph showing device characteristics of an electroluminescent device.

[FIG. 6] A graph showing device characteristics of an electroluminescent device.

[FIG. 7] A graph showing device characteristics of an electroluminescent device.

[FIG. 8] A graph showing device characteristics of an electroluminescent device.

30 [FIG. 9] A graph showing an IR spectrum of quinoxaline derivatives according to the invention.

[FIGS. 10] Photographs of the surfaces of quinoxaline derivatives according to the invention and a BCP thin film.

[Document Name] Abstract

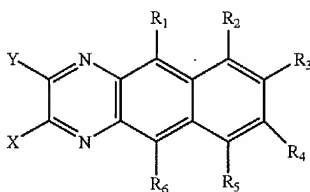
[Abstract]

An object of the invention is to provide quinoxaline derivatives which have excellent electron transportation and hole blocking properties, and which can be formed into a film without being crystallized.

[Means for Solving the Problem]

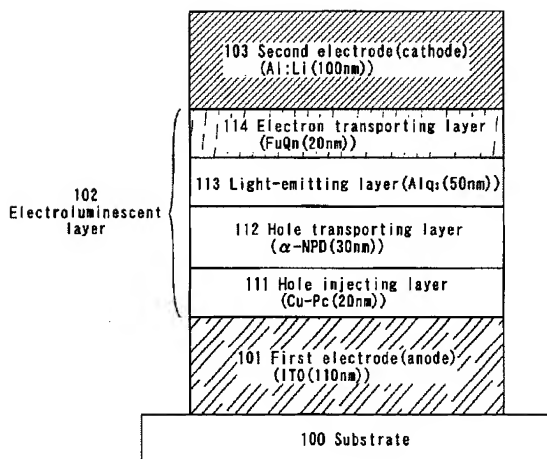
According to the invention, quinoxaline derivatives represented by the general formula [formula 31] is synthesized.

[formula 31]

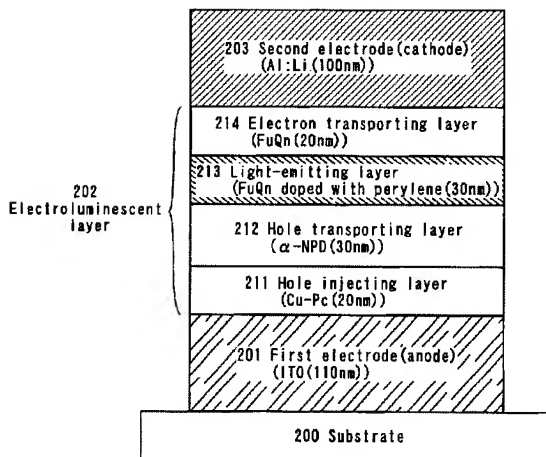


(In the formula, X and Y represent a substituted or unsubstituted aryl group, or a substituted or unsubstituted heterocyclic residue, and R1 to R6 individually represent hydrogen, an alkyl group, an alkoxy group, a substituted or unsubstituted aryl group, and a substituted or unsubstituted heterocyclic residue.) Further, an organic semiconductor device including an electroluminescent device characterized by containing the foregoing quinoxaline derivatives is formed.

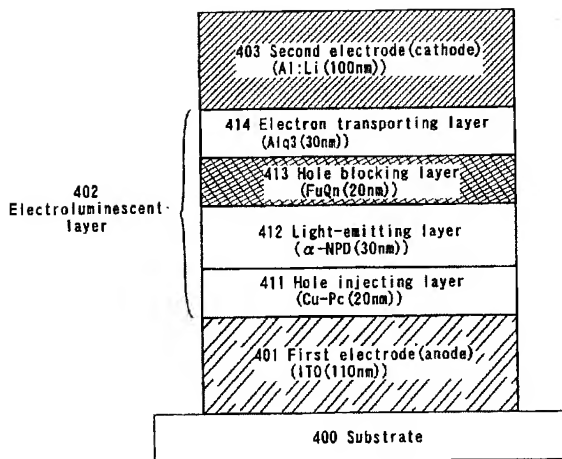
【FIG. 1】



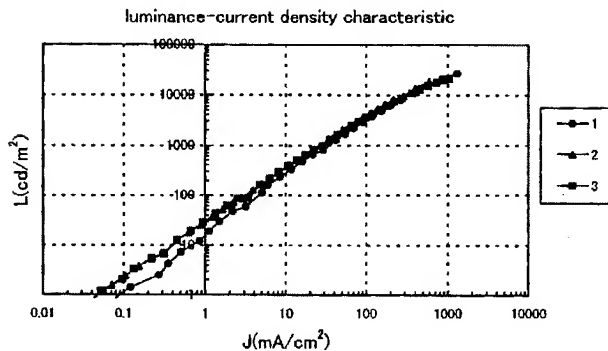
[FIG. 2]



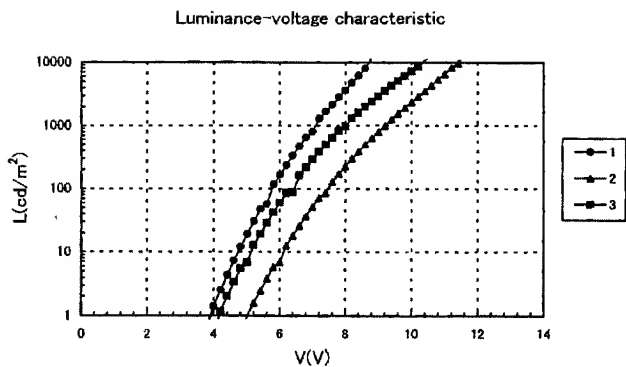
【FIG. 4】



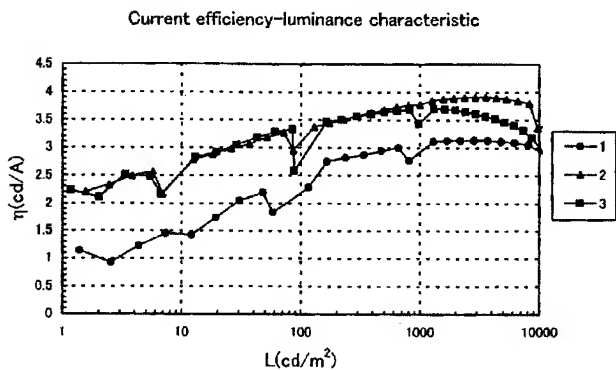
【FIG. 5】



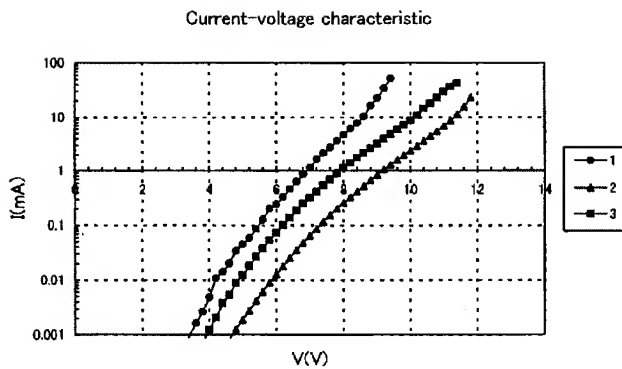
【FIG. 6】



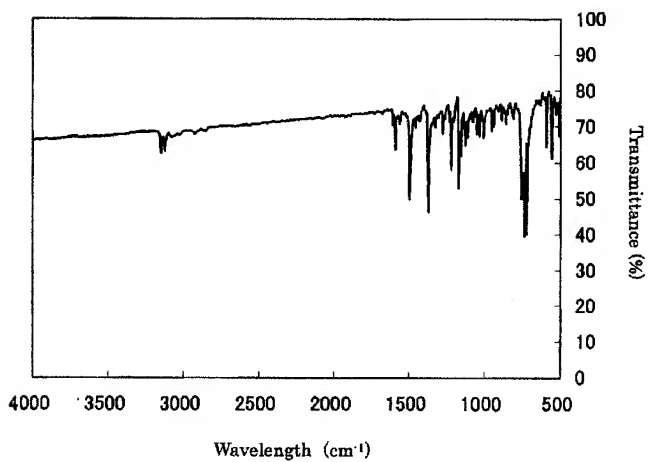
【FIG. 7】



[FIG. 8]

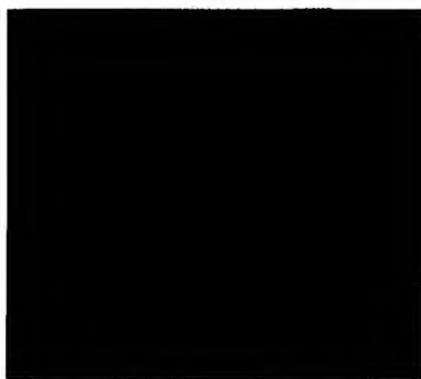


[FIG. 9] IR spectrum (FuQn)



【FIG. 10】

(A)



(B)

